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Pulsating Flow past a Spanwise Rib in a Channel at Moderate Reynolds Numbers

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Abstract—The results of visual investigations and direct numerical simulation of flow past a spanwise rib in a channel in a pulsating external flow at the Reynolds numbers corresponding to transition to turbulence in the separation region downstream of the rib in steady-state flow past the latter are represented. It is shown that the calculated and experimental data are in the adequate accordance. The effect of the forced unsteadiness parameters on the vortex flow structure downstream of the rib is analyzed. Some laws of the formation and evolution of the vortex structure downstream of the rib in a pulsating flow are obtained.

Key words: spanwise rib, flow visualization, forced flow pulsations, direct numerical simulation, starting vortices, spiral motion of fluid.

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The mounting of obstacles in viscous fluid flow leads to separation and formation of either steady-state or quasi-periodic vortex wake behind the body. The characteristic feature of such flows is formation of large-scale vortex structures, their disintegration, and transition to turbulence already at low, of the order of 10^2, Reynolds numbers Re [1–5]. In channel flows, vortex formation and flow turbulization are accompanied by the local enhancement of heat transfer on the channel walls. This opens up possibilities to control the heat transfer processes by means of the purposeful impact on the vortex structure in the separation region through the forced pulsations of the flow velocity. In a series of the experimental investigations [6–8] it was shown that it is possible to achieve reduction of the reattachment length by 1.5–2 times when the mean heat transfer coefficient along this length increases by approximately 60% by disturbing the velocity of turbulent flow ($\mathrm{Re} \sim 10^5$) at the frequencies corresponding to the Strouhal $\mathrm{Sh} \sim 1$ calculated on the basis of the reattachment length in steady-state flow. In [9] similar data on the effect of the forced flow pulsations on the reattachment length behind a backward-facing step were obtained. The effects of increase or reduction in heat transfer of an array of spanwise ribs on the wall as functions of the forced flow pulsation frequency were discussed in [10].

The effect of forced velocity pulsations on laminar flow past bodies seems to be significantly less studied. In [11] the results of the numerical simulation of heat transfer and flow past a circular cylinder are represented for an unconfined viscous pulsating flow in the two-dimensional approximation at $\mathrm{Re} = 100$. It is shown that the forced velocity perturbation frequency actually determines the vortex separation frequency; an increase in the local Nusselt number by approximately 30% was observed. So far, the investigations of pulsating channel flows have not been properly represented in scientific literature. The present paper is devoted to this question. Main attention is concentrated on the features of the effect of the Reynolds number and the forced unsteadiness parameters on the vortex flow structure in the separation region downstream of an obstacle; the conjugated problem of heat transfer enhancement in such flows will be considered in another publication.

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